Communication System based on TETRA

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Abstract—Designing and development of a communication system which is based on TETRA technology, which can be used in trunk mode of operation as well as direct mode of operation. This system is used by Nagpur metro, Maharashtra, India. My study provides a solid introduction to communication system with all the systems available to setup the system and finally the system which is used due to characteristic reasons.

Index terms - APCO, Project 25, APCO-16, NXDN, dPMR, PMR, Tetrapol, TETRA, Common Air Interface, DMO, TMO.

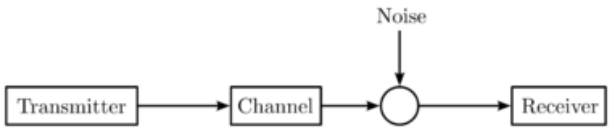
I. INTRODUCTION

In telecommunication, a communication system is an assembly of individual communication networks, transmission systems, relay station, tributary stations, and data terminal equipment (DTE) to form an integral whole system which is interconnecting and interoperable. All the components of communications system focus on a common purpose, are technically compatible, use common procedures, respond to controls, and operate in union.

Having a specific communication system for one integral plan is very necessary, as in, metro systems require a very redundant, fast and reliable communication system with very high priority, for its smooth running. So, setting up a new specific communication system is required.

Figure I

Block diagram of communication system



Systems that are available to setup communication systems are –

a. P25 radio system
b. APCO 16
c. NXDN
d. Tetrapol
e. dPMR
f. Tetra radio system

System requirements for communication system of metro –

a. Efficient and effective radio system.
b. High security of the system.
c. Wireless communication system.
d. High redundancy.
e. Centralized IP based radio system.
f. Replication of the system at fallback to maintain redundancy.
g. Base stations.

II. RELATED WORK

The main problem which came across in wireless or mobile radio was how to overcome the distortion of signals received at the receiver end by a time-varying and frequency-selective propagation path. Waves near the ground do not travel over a single well-defined radio path as in free space, waves are scattered against reflecting obstacles. Reflected waves may add noise destructively, which makes the received signal to disappear or become heavily attenuated at specific locations. A user who is in a moving vehicle, receives a signal that is rapidly distorted in time. This is called ‘fading’.
Digital signal processing (DSP) techniques can lessen these effects to a huge extent. Therefore, today the most critical issues of wireless systems are no longer directly related to multipath fading, but are -

1. Scarcity of radio spectrum therefore, resulting in mutual interference among various users.
2. Portable terminal's power consumption and inadequacy of current battery.

A. Project 25

It is also known as APCO-25. It is a suite of standards for the purpose of digital mobile radio communications proposed for usage by public safety organizations in North America.

Data functionality was added to public safety LMR by implementing a set of common technical standards for digital communication, known as the Association of Public- Safety Communication Officials (APCO) Project 25 (P25). [1]

These radios are an absolute replacement of analogue UHF radios but they increase the ability of transferring data and voice, giving permission for a much more seamless fulfilment of encryption. These radios are usually used by organizations such as police, fire, ambulance, etc which use vehicle-mounted radios with walkie-talkie in-hand usage.

Communication between mobile, portable, and base radios is specified through an open digital protocol called the Common Air Interface (CAI). [2]

There are 2 main phases in P25 system –

a. Phase 1
b. Phase 2

Security flaws –

a. Interoperability challenges
b. Encryption flaws in DES-OFB and ADP ciphers
c. Lapses in encryption
d. Vulnerability of jamming
e. Licensing cost too high

B. APCO 16

It is a US standard of the characteristics of public safety trunked radio systems. The developmental effort was started in 1970's by the APCO. The system was financed by the Law Enforcement Assistance Administration (LEAA). [3]

Characteristics –

a. Time of channel access
b. Automatic recognition of priority
c. Interface of data systems
d. Individuality of users of system
e. Flexibility of command and control
f. Capability of system growth
g. Reuse of frequency
h. Reliable system

Limitations –

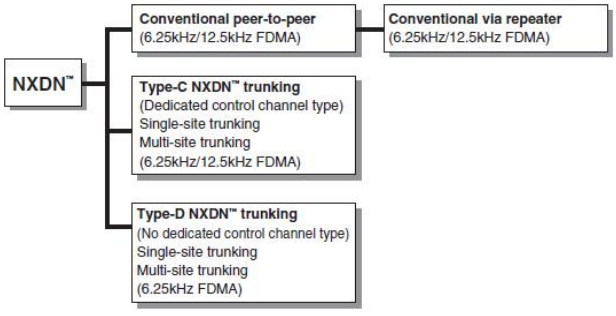
a. Picket fencing – It is a word for the chopping effect sometimes experienced by mobile phone users on the edge of a cell's coverage area. It refers to the way portions of speech are stripped from the conversation, as if the listener was walking by a picket fence.
b. Foliage interference – The presence of foliage in the propagation channel can lead to severe signal attenuation. The path loss is due to foliage effect, shadowing and multipath dispersion are also due to foliage effect. Generally, the foliage effects on the wireless communications.
c. Abrupt signal fall
d. Health concern effects from 800 MHz transmitters

C. NXDN

It is an open standard Common Air Interface (CAI) technical protocol for mobile communications. It was designed by Icom Incorporated and Kenwood Corporation. NXDN is implemented in IDAS system by Icom and NEXEDGE by Kenwood. [4]

Figure II

Types of NXDN



Limitations –

Voice reproduction quality trade off's are made in return to minimize the raw bit rate of the transmission.
It results in artifacts and compromise in frequency response in reproduced speech. Encoders and other compression schemes which are highly optimized for speech are often unsuitable for non-speech audio. [5]

D. dPMR

dPMR or digital private mobile radio, is a Common Air Interface (CAI) for digital mobile communications. dPMR is an open, non-proprietary standard that was developed by the European Telecommunications Standards Institute (ETSI) and published under the reference ETSI TS 102 658.
Security, improved speech quality and high speed data are major objectives for a digital private mobile radio (DPMR) system, in addition to improved spectrum efficiency. As well as providing these features, there is the need to provide traditional PMR services such as group call, open channel calls and emergency calls. [6]

Specifications –

a. Access method: FDMA
b. Transmission rate: 4,800 bit/s
c. Modulation: four-level FSK

The dPMR system for digital trunked system consists of four parts: speech codec module, Digital Base-band (DBB) unit, digital IF transceiver, and Radio Frequency (RF) part. [7]

They are ideally suited to recreational and professional users who do not need wide area coverage with base stations and repeaters.

E. TETRAPOL

TETRAPOL, defined by the TETRAPOL Publicly Available Specification in 1988, is a digital public mobile radio technology designed for mission-critical public safety users. It guarantees autonomy and security. [8]

A TETRAPOL BS can handle up to 24 radio channels. The TETRAPOL channel access is based on frequency Division Multiple Access (FDMA) with a channel spacing of 12.5 kHz. The gross modulation bit rate is 8kbit/s using binary Gaussian Minimum Shi Keying (GMSK) modulation. The net bit rate for data transmission is 4.6 kbit/s (low protected data) and 3.6kbit/s (high protected data), the latter w used for simulations. The moat integral part of the standard is end to end encryption. [9]

It is a continuous wave transmission that does not pulse.

It utilizes frequency division multiple access (FDMA) which breaks various channels amongst users which are each given to users from the available bandwidth for their permanent use. Better range and better coverage is provided than other channel access methods, providing better reception over wider cell coverage. A more robust air interface is provided by the use of dedicated control channel.

TETRAPOL uses a robust binary modulation with a smaller bandwidth leading to less transmission errors with the same radio conditions. [9]

III. TETRA

Terrestrial Trunked Radio (TETRA) is an ETSI standard for Professional Mobile Radio (PMR) users such as public safety services (police, fire, etc.) and the commercial sector (railways, buses, taxis, etc.). Many organizations have already adopted TETRA for the development of their network infrastructure, mainly for voice communications. However, it has been shown that low rate compressed video could also be accommodated. [10]

It uses time-division multiple access (TDMA) with 4 user channels on one radio carrier and 25 kHz spacing between carriers. Both point-to-point and point-to-multipoint transfer can be used.

TETRA Mobile Stations (MS) can communicate in direct-mode operation (DMO) or trunked-mode operation (TMO) using switching and management infrastructure. Situations where network is not available, it also allows direct communications.

It provides for authentication of terminals for infrastructure and vice versa. For security against eavesdropping, end to end encryption and air interface encryption is also available.

Most of the essential core ETSI standardization work by ETSI Project TETRA (EPT) has been completed and the main effort is now focused on maintenance and enhancement activities. [11]

The approach taken is to emulate a TETRA transmission link for a number of different signal to interference and noise ratios but for the same environment and fast fading. The resulting output of hard and soft receiver errors is recorded in a file for each of these signal to interference and noise ratios. In order to model the channel, the transmitted data stream is combined with the recorded errors for the signal to noise ratio which is actually encountered. Since the physical layer (OS1 Layer 1) is treated as a virtual bit pipe within the TETRA system (and in particular, modulation and detection is independent of received channel quality), adding these errors to the transmitted bit stream completely emulates the channel. This signal to noise ratio can be controlled by the high level simulator. The result is a bit steam with individual

bit errors, without the computational overhead of running the link level simulations at the time. [12]

Advantages

The main advantages are -

a. High geographical coverage - lower frequency gives longer range.
b. During a voice call, the communications are not interrupted when moving to another network site.
c. Direct mode - In no network conditions, radios can use this mode where the channels are shared directly.
d. Gateway mode - where a single radio can act as relay infrastructure for other radios.
e. It provides one-to-one trunked link between sets.
f. Tetra provides authentication, air-interface encryption and end to end encryption.

Disadvantages -

a. Requires a linear amplifier to meet the stringent RF specifications that allow it to exist alongside other radio services.
b. Data transfer is slow by modern standards.

Technical Characteristics

Modulation scheme - $\pi/4$ differential quadrature phase-shift keying
Baud rate – 18,000 symbols per second I.E 36,000 bits per second

The base stations of TETRA normally send and receive simultaneously. It also uses frequency division technique and time division technique. The radios only send on 1 slot/4 and receive on the same.
Signals of speech are divided at 8 kHz and after transmission are suppressed using a vocoder. It leads to creation of a data stream of 4.567 kilobits per seconds. The produced stream is encoded for error-protection before transmitting them to allow proper, error free decoding.
Data rate - 7.2 kbps.
Capacity - 17/18 frames.
One slot contains 255 symbols that can be used, the time which is left is used for synchronization.
One single frame has 4 slots, and a multi-frame which has a duration of 1.02 seconds.

Figure III.

Network of the TETRA system

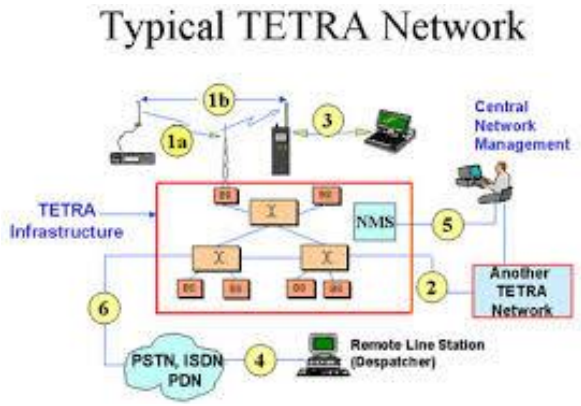


TABLE I.

COMMUNICATION SYSTEMS: A COMPARATIVE STUDY

Characteristics	**P 25**	**APCO 16**	**NXDN**	**dPMR**	**Tetrapol**	**TETRA**
Access technique	FDMA	FDMA	FDMA	FDMA	FDMA	TDMA
Modulation	CQPSK and HDQPSK	C4FM	4-level FSK	4-level FSK	GMSK	$\pi/4$ DQPSK
Bandwidth	25 kHz to 12.5 kHz	25 kHz to 30 kHz	6.25 kHz	6.25 kHz	10 kHz	25 kHz
Data rate	4800 bps	4800 bps	9600 bps	4800 bps	7.6 kbps	36,000 bps

IV. DESIGNING USING TETRA

The frequency allotted for this project is 380- 400 MHz. [13]

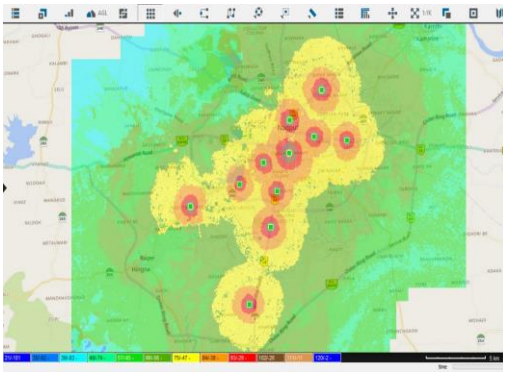
The main 2 aims of a communication system using TETRA is –

A. Coverage – Trunking facility is provided to provide coverage to the complete project. Handoff is done between different BSC's depending upon the hysteresis level.
B. Capacity - It is decided using the Erlang formulas, based on the traffic intensity, average number of calls, average duration of calls. [14]

Designing of a communication system based on TETRA involves the following steps –

A. Writing of conceptual design document – The primary designing of the system based on the requirements are done in this document.
B. Site search – This is done using a software – Telecom ICS by ATDI.

Figure IV.
Results of antenna coverage using Telecom ICS



C. Setting up of BSC – There are2 types of BSC provided by DAMM, used in this project – Outdoor unit and indoor unit. Outdoor unit is used where we cannot set up a safe house for the system and an indoor unit is used where we can set up a safe house for the equipment. For Nagpur metro project, all BSC's used are indoor BSC.
D. Testing – The testing of the BSC is performed under various conditions. There are various tests that are performed, like, physical testing, chemical testing, etc.
E. The BSC are pre-programmed about their radios, which are provided signal using that one specific BSC.

V. CONCLUSION

By the end of this project, communication system based on TETRA to be used by Nagpur metro will be ready for public use and can be handed over to Maharashtra government in India.

VI. REFERENCES

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